



SHERWIN-WILLIAMS.

THE SHERWIN-WILLIAMS COMPANY
Environmental, Health & Regulatory Services
101 Prospect Avenue NW
Cleveland, Ohio 44115-1075
Facsimile: (216) 566-2730

April 30, 2009

Mr. Ray Klimcsak
U.S. Environmental Protection Agency – Region 2
290 Broadway 19th Floor
New York, New York 10007-1866

**RE: Kirkwood Lake Investigation Report
Evaluation of Sampling Results
Voorhees Township and Lindenwold Borough, NJ**

The Sherwin-Williams Company Sites – RI/FS Activities
Gibbsboro, New Jersey
Administrative Order Index No. II CERCLA-02-99-2035

Dear Mr. Klimcsak:

Enclosed please find the above-referenced Kirkwood Lake Investigation Report for your review. Sherwin-Williams has prepared this report to evaluate the sampling results and remedial investigation activities conducted in Kirkwood Lake located in Voorhees Township and Lindenwold Borough, New Jersey.

Should you have any questions or comments, please do not hesitate to contact me at (216) 566-1794 or via e-mail at mlcapichioni@sherwin.com.

Sincerely,

Mary Lou Capichioni
Director Remediation Services

cc: J. Doyon, NJDEP (4 copies)
C. Fishman – Camden County Parks Department
J. Gerulis, Sherwin-Williams (w/o attachments)
A. Danzig, Sherwin-Williams (w/o attachments)
S. Peticolas, Gibbons, P.C. (w/o attachments)
H. Martin, ELM
S. Jones, Weston Solutions
A. Fischer, Weston
S. Clough, Weston
R. Mattuck, Gradient

**KIRKWOOD LAKE INVESTIGATION REPORT
EVALUATION OF SAMPLING RESULTS
VOORHEES TOWNSHIP and LINDENWOLD BOROUGH, NJ**

April 30, 2009

AOC Index Number: No. II
CERCLA-02-99-2035

Prepared for:

THE SHERWIN-WILLIAMS COMPANY
101 Prospect Avenue, NW
Cleveland, Ohio 44115

Prepared by:

WESTON SOLUTIONS, INC.
205 Campus Drive
Edison, New Jersey 08837

W.O.:20076.022.077

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1.0 INTRODUCTION

As part of The Sherwin-Williams Company (Sherwin-Williams) ongoing Remedial Investigation/Feasibility Study (RI/FS) of the Sherwin-Williams sites located in Gibbsboro, New Jersey, soil, sediment, surface water and pore water samples were collected at Kirkwood Lake, located in Voorhees and Lindenwold Townships in Camden County, New Jersey. The objective of the sampling was to characterize the nature and extent of constituents found in Kirkwood Lake that may be related to the historical operations from the upstream Sherwin-Williams sites located in Gibbsboro, New Jersey.

A total of 224 sediment samples (and 12 duplicates), 75 soil samples (and two duplicates), 10 surface water samples (and one duplicate) and 2 pore water samples were collected from Kirkwood Lake during the course of two phases of investigation. The sample locations from both phases of investigation are presented on Figure 1.

The first phase of investigation, conducted in October/November 2007, consisted of collecting samples of the fine-grained organic material which comprises the top layer of sediment within the lake, soil from the southern bank of Kirkwood Lake, and pore and surface water samples from within Kirkwood Lake. Also included in this phase was the collection of soil and sediment samples from the Cooper River, beginning at the Kirkwood Lake dam outfall and extending approximately 150 feet downstream of the White Horse Pike overpass.

The second phase of the Kirkwood Lake investigation was conducted during June 2008. This phase consisted of collecting samples of the deeper, coarse-grained material from 26 locations within Kirkwood Lake. During this phase, six sediment samples were also collected and analyzed for Simultaneously Extracted Metals/Acid Volatile Sulfides (SEM/AVS).

All of these activities were conducted in accordance with work plans approved by the United States Environmental Protection Agency (EPA) Region II New Jersey Remediation Branch. The first phase of sampling was performed as proposed in the *Revised Kirkwood Lake Work Plan, RI/FS Activities* dated October 24, 2007. Based on the results of the October/November 2007 sediment sampling, Sherwin-Williams prepared and submitted to the EPA the *Revised Submission of Sediment Sampling Results and Proposal to Conduct Deep Sediment Characterization - Kirkwood Lake*, dated June 19, 2008.

The June 19, 2008 work plan presented the results of the investigation conducted in October/November 2007, and proposed several locations where samples of the deeper coarse-grained material would be collected. The June 19, 2008 work plan also stated that, when the analytical results for the deeper coarse-grained material were received and analyzed, a report presenting the results of the sediment, soil, surface water and pore water sampling conducted during both phases of investigation would be prepared and submitted. This report provides the results of all samples collected during the two phases of investigation.

The report is organized by sampling media. A discussion of the sediment sampling methods and results is followed by a discussion of the soil, surface water, and pore water sampling methods and results.

2.0 SCREENING CRITERIA

Consistent with the investigations of the Sherwin-Williams sites located in Gibbsboro, New Jersey, screening criteria have been applied in the evaluation of the analytical results obtained during the investigation of Kirkwood Lake. Additionally, as discussed in Section 3.1, the screening criteria were also used in the field during the second sampling event to guide the collection of samples for laboratory analysis and determine the depths at which sample collection would be terminated.

The use of screening criteria to evaluate whether the extent of contamination had been adequately delineated and to select analytical parameters to be used in subsequent investigations of individual Sherwin-Williams sites located in Gibbsboro, New Jersey or portions of sites was originally introduced in the Sherwin-Williams January 13, 2005 letter to Ms. Carole Peterson. In this letter, it was proposed that:

- Analytical results from soil samples would be compared to the most stringent of the New Jersey Department of Protection (NJDEP) Residential Direct Contact Soil Cleanup Criteria (RDCSCC) or the EPA Region 9 Preliminary Remediation Goals (PRGs);
- Analytical results from sediment samples would be compared to the Lowest Effect Levels (LELs), as published by the NJDEP in its 1998 *Guidance for Sediment Quality Evaluations*; and
- Analytical results from ground water samples would be compared to the NJDEP Class IIA Ground Water Quality Standards (GWQS).

Screening criteria for surface water were not specified in the January 13, 2005 letter.

The screening criteria were subsequently refined, following collection and analysis of the results of the initial investigation of Hilliard Creek, to incorporate consideration of a preliminary background concentration for arsenic in soil. It was concluded that the screening criteria for arsenic was lower than the naturally-occurring concentrations in soil. Based on this evaluation, it was proposed to EPA that a screening criterion of 8 mg/Kg be used for arsenic in soil samples. The LEL of 6 mg/Kg would continue to be used for sediment samples.

The NJDEP LELs were used to evaluate the results of the initial sediment sampling results for Kirkwood Lake, as presented in the *Revised Kirkwood Lake Work Plan, RI/FS Activities* dated October 24, 2007. These criteria were also used for field screening the deeper coarse-grained sediment cores collected during the June 2008 sampling event, and for selecting samples for laboratory analysis.

Subsequent to the June 2008 sampling event, the NJDEP promulgated and adopted new soil standards for both residential and non-residential land use scenarios. Further, the EPA has combined several of the previous region-specific guidance documents regarding screening criteria for various media into a single document called the "Regional Screening Levels" (RSL). Finally, the NJDEP has requested that surface water results be compared to NJDEP surface water standards. Therefore, for purposes of this report, the following screening criteria were used to evaluate the sediment, soil, surface water and pore water data that were collected during both the October/November 2007, and the June 2008 investigations.

- The screening criteria for soil are the NJDEP Residential Direct Contact Soil Remediation Standard (RDCSRS). These criteria were used to evaluate soil samples from all soil locations, regardless of land use. These standards were adopted by NJDEP and replace the previously-used RDCSCC.
- Sediment samples were compared to the NJDEP LELs for freshwater sediment as published in July 2008. These criteria are generally similar to the previous LELs published by NJDEP in its 1998 guidance document.
- Surface water and pore water sample results were compared to the NJDEP chronic surface water criteria for fresh water (FW2) aquatic protection (NJAC 7:9B-1.14d). These criteria were chosen because the primary receptors to surface water in Kirkwood Lake are considered ecological in nature. These criteria were also used to screen the pore water samples because the primary purpose of the pore water sampling was to evaluate the potential exposure of ecological receptors to constituents present in the sediment. It is noted that, for some metals, the NJDEP FW2 surface water criteria are a function of hardness, and have been calculated using the average hardness level measured in Kirkwood Lake during the surface water sampling.

Ground water samples were not collected as part of the Kirkwood Lake investigation, so no screening criteria for ground water have been applied.

3.0 SEDIMENT INVESTIGATION

Presented in this section are the sampling methodologies used during the October/November 2007, and June 2008 investigations, and the results of the investigations. Both the physical characteristics of the sediment and the distribution of constituents found in sediment are discussed.

3.1 Sampling Methods and Locations

A total of 224 unique sediment samples and 12 duplicate samples were collected during the two sampling events. The sample locations are presented on Figure 1. Each sample location was identified and its coordinates recorded using a global positioning system (GPS). The samples were generally classified in the field logs as either "soft" or "organic-rich silt" *to describe the fine-grained organic rich material* or "hard" to describe

the *deeper coarse-grained sediment*. These descriptors were based upon the field team's ability to penetrate the sediments.

Sediment samples were collected using a variety of methods. The sampling device selection was based upon the depth of the sample being collected and the field conditions observed at the time of sampling. Sediment samples were collected from the upper 6-inch interval using an Ekman sampler (i.e., clamshell sampler). Deeper samples of the fine-grained organic material were collected either utilizing a suction sediment coring device or by a Vibracore™ sampling tool. Samples of the deeper coarse-grained material were collected with a Vibracore™ in those locations accessible by boat and with the suction sediment coring device at shoreline locations that were not readily accessible with the Vibracore™ sampler due to the shallow water depth. All sampling equipment was decontaminated prior to each use.

Sediment sampling activities began on October 3, 2007 and it was initially presumed, based on the physical conditions observed in previous sediment samples collected at Bridgewood Lake, that the sediments would be too saturated to allow collection of reliable data with the X-ray fluorescence (XRF) unit. However, upon evaluation of the initial sediment samples collected from Kirkwood Lake, it was determined that XRF screening would be possible for many of the sediment samples, depending upon the consistency of the sample. Beginning October 17, 2007, a portable XRF unit was used to screen sediments for the presence of metals and provide guidance on the collection of samples for laboratory analysis. Screening criteria for arsenic and lead was based on the NJDEP LEL for sediment established at 6 mg/kg and 31 mg/kg, respectively. The suitability for XRF screening was determined on a sample-by-sample basis.

Based on the results of the XRF screening, samples were collected for laboratory analysis from each location as per the approved sampling protocol for each sampling event (see below). The sample collection was documented, and the homogenized aliquot was transferred to the appropriate sample containers as specified in the EPA-approved RI/FS Quality Assurance Project Plan (QAPP). The sample was then immediately preserved with ice for laboratory delivery and analysis.

3.1.1 October/November 2007 Sediment Sampling Event

The sediment sampling program for Kirkwood Lake was designed to obtain the information needed to characterize the physical conditions (thickness, grain size and organic carbon content), and distribution of chemical constituents in fine-grained organic material. As per the approved work plan, these results would be used to determine where sampling of the underlying deeper coarse-grained material would subsequently be conducted.

Sediment samples were collected from Kirkwood Lake along selected transects that ran from the northern to southern shoreline, as well as from coves and other potential deposition areas. A total of 17 transects within Kirkwood Lake were included in the sampling. Sediment sample locations were sited at each shoreline and then subsequently spaced approximately 50 feet apart along each transect.

Sediment samples were also collected from the Cooper River downstream of the Kirkwood Lake dam outfall. Sediment samples were collected from the center of the Cooper River at locations beginning at the outfall of Kirkwood Lake to the Cooper River and at three additional locations 50 feet, 100 feet, and 150 feet downstream of the White Horse Pike overpass.

The approved sampling approach provided for the collection of up to three sediment samples per sample location based on the thickness of the fine-grained organic layer:

- A sediment sample was collected from the uppermost 6 inches of the first encountered sediment (AA-AB interval) at all sediment-sampling locations.
- If the sediment thickness was found to be greater than 1.5 feet but less than 4 feet, then one additional sample of the fine-grained organic material was collected from the 6-inch interval immediately above the underlying deeper coarse-grained material. In this situation, two sediment samples were collected.
- If the sediment thickness was greater than 4 feet, a sample was obtained from the top 6 inches, a second sample was collected from the 6-inch interval immediately above the underlying deeper coarse-grained material, and a third sample was collected from an intermediate depth interval depending upon screening results or field observations.

All sediment samples collected during the October/November 2007 sampling were submitted to Test America Laboratories (Test America) for Target Compound List (TCL) polynuclear aromatic hydrocarbons (PAHs), TCL polychlorinated biphenyls (PCBs), Target Analyte List (TAL) metals (including cyanide), pH, total organic carbon (TOC), grain size, and percent solid analyses.

3.1.2 June 2008 Sediment Sampling Event

Samples of the deeper coarse-grained material were collected from 26 locations during the June 2008 sampling, based on a review of the results of the October/November 2007 sampling. The final locations and depths incorporated comments by the EPA. Locations were included from each of the 17 transects from which samples were collected during the October/November 2007 sampling, and represented center, shoreline and intermediate locations across Kirkwood Lake.

The analytical parameters for the June 2008 sampling were selected based on the results obtained during the October/November 2007 sampling event. During the initial sampling, only TAL metals, PAHs and PCBs were found at concentrations greater than their respective screening criteria. The PAHs and PCBs were found primarily in sediment samples obtained from the top 0.5 feet of the fine-grained organic material, and in the few locations where either constituent was found in deeper sediment intervals, the concentrations approached the screening criteria. Therefore, the

analytical parameters selected for the June 2008 sampling event were TAL metals, TOC, pH, grain size, and percent solids.

Sample collection, screening and selection of the deeper coarse-grained sediment samples for laboratory analysis were conducted in accordance with the following protocol:

- The depth of the fine-grained organic material was gauged to provide an understanding of the depth at which the deeper coarse-grained material would be encountered, and the total depths at which the samples of the deeper coarse-grained material would be collected.
- A VibracoreTM was advanced to the top of the deeper coarse-grained material, and a 3-foot core of the deeper coarse-grained material was collected. The 3-foot core was brought to the surface and the XRF unit was used to screen the 0.0-0.5-foot, 1.5-2.0-foot, and 2.5-3.0-foot intervals beneath the fine-grained organic material of each core for the presence of lead and arsenic.
- If arsenic or lead were not found at concentrations exceeding the LEL (the established screening criteria), only the sample from the 0.0-0.5-foot interval beneath the fine-grained organic material was collected for laboratory analysis.
- If the XRF screening found arsenic or lead at concentrations greater than the LEL at the 0.0-0.5-foot interval, then the samples from both the 0.0-0.5-foot and 1.5-2.0-foot intervals beneath the fine-grained organic material were collected for laboratory analysis.
- If the XRF screening found arsenic or lead at concentrations greater than the LEL in the 2.5-3.0-foot interval beneath the fine-grained organic material, then the samples from all three intervals were collected for laboratory analysis. If XRF screening indicated that concentrations of arsenic or lead may be present above the LEL at depths greater than 2.5-3.0 feet, additional sampling was conducted until the XRF analysis found neither lead nor arsenic at a concentration greater than the LEL. A sample was collected from this depth for laboratory analysis.

In addition, six samples were also collected for SEM/AVS analysis that is described in greater detail in Section 3.4.

3.2 Sediment Investigation Results

The analytical results for all sediment samples collected during the October/November 2007 and June 2008 investigations are discussed in this section. These include results of the October/November 2007 investigation previously submitted to the EPA, and the results for the June 2008 sampling. The sample analytical summary tables and laboratory analytical results for these samples are provided respectively in Tables 1A and 1B included on the accompanying CD.

To assist in review of the results, the sediment data are further presented in the following figures:

Figures 2, 3A and 3B: Analytical results for arsenic and lead in sediment are presented in Figure 2; the data are compared with their respective sediment screening criteria. Only the arsenic and lead analytical results greater than the NJDEP LELs are shown on Figures 3A and 3B.

Figures 3A and 3B: All constituents detected in sediment at concentrations above their respective LEL are presented. As stated previously, the results presented for constituents other than TAL metals are from only the October/November 2007 sampling event.

Figures 4A-4D: Analytical results for arsenic, lead, percent solids and TOC are shown on sediment cross-section profiles for each transect.

The following updates the discussions of sediment distribution and physical properties, and the distribution of constituents in the sediment initially presented in the *Revised Submission of Sediment Sampling Results and Proposal to Conduct Deep Sediment Characterization - Kirkwood Lake*, dated June 19, 2008, incorporating the results of the June 2008 sampling.

3.2.1 Sediment Distribution and Physical Properties

As shown on Figures 4A through 4D, Kirkwood Lake is a shallow water body, averaging between a 2-3-foot depth in the lake center and 1-foot or less along the perimeter shoreline. The fine-grained organic material ranged in thickness from approximately 2-3 feet thick throughout the majority of the lake. It is thinner or absent along much of the shoreline, where the lake is shallowest. Thicker accumulations of the fine-grained organic material (4-5 feet) were seen in the southern portion of the lake, immediately upstream of the dam outfall to the Cooper River, at Transect KWT-2, and in Transect KWT-23, located approximately 1,000 feet up stream of the dam outfall to the Cooper River.

A relatively well-defined center channel runs east-west along the length of the lake. Within this channel, the deeper coarse-grained material forms a relatively flat bottom, over which the fine-grained organic material has been deposited. The fine-grained organic material is thickest within the center channel, becoming thinner towards the shoreline.

The fine-grained organic material was generally defined as having low percent solids (generally 30% or less) and high TOC (100,000 mg/Kg or greater). Based on the grain size analyses that were conducted, the fine-grained organic material consists primarily of silts, clays and fine sands, and contains little medium to coarse sands or gravel.

The underlying deeper coarse-grained material contained solids contents of 70% or greater and TOC levels in the range of 5,000 mg/Kg or less. The grain size analyses

presented in Table 1B show that fine sands comprise the greatest percentage of soil in these samples, but other sizes, ranging from silts to gravels, are also present.

Samples with percent solids values between 30% and 70% and TOC levels greater than 5,000 mg/Kg but less than 100,000 mg/Kg were likely composed of a mix of the fine-grained organic material and the deeper coarse-grained material.

3.3 Distribution of Chemical Constituents in Sediment

The following discusses the distribution and relative magnitude of the constituents found in sediment at levels greater than the LEL screening criteria. As stated previously, samples collected during the October/November 2007 sampling event were analyzed for TAL metals, PAHs, PCBs, TOC and percent solids; while the samples collected during the June 2008 sampling event were analyzed for TAL metals, TOC and percent solids. Therefore, the discussion of the distribution of constituents other than TAL metals is based exclusively on the results of the October/November 2007 sampling.

The results of both sampling events have been tabulated to present the frequency at which each constituent was detected, and the frequency at which it was found at a concentration greater than its LEL, by the depth interval at which the samples were collected. This sediment statistical analysis summary is presented on Table 1C included on the accompanying CD.

3.3.1 Polynuclear Aromatic Hydrocarbons (PAHs)

PAHs were found at concentrations above NJDEP LEL in 89 of the 183 sediment samples collected during the October/November 2007 sampling event. As presented on Table 1B, the LELs for the individual PAHs are all less than 1 mg/kg, and for acenaphthene, acenaphthylene and dibenzo(a,h)anthracene the screening criteria less than 0.1 mg/kg. As a result, even relatively low levels of the individual PAHs exceed the screening criteria.

Both the highest concentrations and the greatest frequency of detection of PAHs were observed in samples obtained from the 0.0-0.5-foot sampling interval. This trend is illustrated by the distribution and concentration profile of benzo(k)fluoranthene [B(k)f], the PAH found most frequently in Kirkwood Lake sediment at a concentration greater than the LEL.

B(k)f was found in almost 60% of the samples collected from the 0.0-0.5-foot interval at a concentration exceeding the screening criterion of 0.24 mg/Kg. However, B(k)f was found at a concentration greater than its screening criterion in less than one-third of the samples collected from the 2.0-2.5-foot interval, and in approximately one-quarter of the samples collected at depths greater than 2.5 feet. The highest B(k)f concentration in the 0.0-0.5-foot interval was 11 mg/Kg, while the highest concentration in the 2.0-2.5-foot interval was 6.8 mg/Kg. The maximum concentration in the 2.0-2.5-foot interval was 4.5 mg/Kg.

A similar pattern, in which both the highest frequency of detection and the highest concentrations are found in the 0.0-0.5-foot interval, is observed for all of the individual PAHs, with the exceptions of acenaphthene, acenaphthylene and naphthalene. Acenaphthene and acenaphthylene were found in deeper sediment at a somewhat higher frequency than in the surface sediment, but the highest concentrations of each constituent were observed in the surface sediment samples. Naphthalene was found at a concentration greater than its screening criterion in only one of the 183 samples collected, and, therefore, no trend can be established.

Several PAHs were found in the sediment samples from the Cooper River down stream of the Kirkwood Lake Dam outfall at sample location KWDD0009 at concentrations greater than their respective LELs. Acenaphthene was also found at location KWDD0109 at a concentration above its LEL.

3.3.2 Polychlorinated Biphenyls (PCBs)

PCBs, Aroclors 1254, and 1260, were found in 62 of the 175 sediment samples analyzed for PCBs at concentrations greater than ecological screening criteria. Similar to the ecological screening criteria for PAHs, the LELs for PCBs are very low, with the screening criteria for each individual Aroclor less than 0.1 mg/Kg. As a result, even relatively low concentrations of PCBs exceed the screening criteria.

PCBs were found most frequently in the sediment samples obtained from the 0.0-0.5-foot interval. Within this interval, PCBs were detected in almost one-half of the samples collected, and in the majority of these samples, the PCBs were present at a concentration greater than the LELs. Comparatively, PCBs were found in approximately 15% of the samples obtained from 1.5-2.0 feet and deeper.

Aroclor 1254 was the most frequently found Aroclor, and was detected in approximately one-third of all of the samples collected. Aroclors 1016 and 1248 were not detected in any samples at concentrations greater than the method detection limit. Aroclor 1242 was found in less than 5% of the samples collected, while Aroclor 1260 was found in approximately 10% of the samples collected.

Where found, concentrations of individual Aroclors ranged from 0.027 mg/kg to 0.62 mg/kg. The concentrations of PCBs in the 0.0-0.5-foot interval, were generally comparable to the PCB concentrations found at the 2.0-2.5-foot and 2.5-3.0-foot intervals. In the limited number of samples collected deeper than 3.0 feet, PCBs were found infrequently and at concentrations approaching the method detection limit.

No PCBs were found at concentrations greater than ecological screening criteria in any of the samples obtained from the Cooper River down stream of the Kirkwood Lake dam.

3.3.3 Target Analyte List Metals

Several metals were found in sediment at concentrations exceeding their respective screening criteria. In addition to lead and arsenic, these include aluminum, cadmium,

chromium, copper, mercury, nickel, silver, and zinc. These metals were all found at levels above screening criteria in the 0.0-0.5-foot interval, but the vertical distribution of the metals in the sediment column varied. For example:

- Aluminum was found only in sediment from the 0.0-0.5-foot interval at a concentration greater than its LEL. Similar to aluminum, silver was found almost exclusively in the surface sediment (only one sample below the 0.0-0.5-foot interval contained silver at a concentration greater than the LEL).
- Mercury and nickel were found throughout the vertical extent of the fine-grained organic material. Similar to the vertical profiles for PAHs and PCBs, the most frequent detection at concentrations greater than their respective LEL and the highest concentration of each were found in surface sediment.
- Arsenic, although present at concentrations greater than its LEL throughout the sediment column, had the highest concentrations at the bottom of the fine-grained organic material, at depths of 1.5-3.0 feet. The frequency of detection at concentrations greater than its LEL were generally comparable throughout the fine-grained organic material, with approximately 60-80% of the samples containing arsenic at a concentration greater than the LEL.

Arsenic was also found at concentrations greater than the LEL in several samples collected from the deeper coarse-grained sediment. At location KWDD-0112, arsenic was found at the 4.5-5.5-foot interval at a concentration of 28.1 mg/Kg; and at the 5.5-6.0-foot interval it was found at 25.4 mg/Kg. Additionally, at location KWDD-0038, arsenic was found at depths ranging from 4.5-5.0 feet to 10.5-11.0 feet at concentrations ranging from 12.9 – 25.3 mg/Kg. The arsenic concentrations at the deepest intervals were 12.9 mg/Kg and 18.1 mg/Kg. At these depths, the sediment is most appropriately viewed as soil, not sediment since ecological exposures are not occurring given the depth of the sediment. Therefore, delineation of arsenic to the screening criteria for soil of 19 mg/Kg has been achieved.

- The vertical distribution of lead was similar to that observed for arsenic, except that it was not found in the deeper coarse-grained material at a concentration greater than the LEL. Lead was found at concentrations greater than the LEL at all intervals within the fine-grained organic material. The frequency of detection at concentrations greater than the LEL was approximately 60-85%. The highest concentrations of lead were found in the surface sediment, but similar levels were also found at the bottom of the fine-grained organic material.

Although not definitive, the differing vertical distribution of the various metals supports a conclusion that different discharge mechanisms are responsible for some or all of the metals found at concentrations greater than the LEL. These mechanisms would include downstream transport of constituents initially discharged at one or more of the Sherwin-Williams sites in Gibbsboro, New Jersey, discharges of other anthropogenic compounds via storm water runoff or atmospheric deposition, or erosion and discharge of naturally

occurring metals. Additional evaluation is needed, however, to develop final conclusions regarding the source(s) of the various metals.

Sediment samples obtained in the Cooper River downstream of the Kirkwood Lake outfall contained arsenic, lead and chromium at concentrations slightly, or moderately greater than their respective LELs. Arsenic was found at concentrations ranging from 6.1 mg/Kg to 13.2 mg/Kg (LEL = 6 mg/Kg), chromium was found at concentrations ranging from 31.6 mg/Kg – 47.0 mg/Kg (LEL = 26 mg/Kg), and lead was found at concentrations ranging from 55.4 – 154 mg/Kg (LEL = 31 mg/Kg). Lead was the only metal found at location KWDD0009, the most downstream location, at a concentration greater than the LEL.

As with the samples obtained from the main body of Kirkwood Lake, the source(s) of the metals found in the samples downstream of the Kirkwood Lake outfall are unclear. This portion of the river is in close proximity to both White Horse Pike and the PATCO rail lines, both of which could be considered potential sources of the lead found in sediment. Additionally, the concentrations of arsenic observed in sediment, although greater than the LEL, are less than the NJDEP RDCSRS, which is based on a statewide background concentration. Therefore, it is possible that some component of the arsenic is attributable to natural conditions. Similarly, although the chromium concentrations exceed the LEL, the concentrations observed (31.6 mg/Kg – 47.0 mg/Kg) are within the range of natural background concentration found in Eastern United States soils (EPA. 2008).

3.3.4 Quality Assurance and Data Completeness

A query of the Kirkwood Lake database showed that various metals, PAHs, and Aroclors were detected in sediment samples. Excluding results of TOC, grain size, and pH, there are 9,817 sediment results, of which, 5,664 are metals. A total of 130 results (out of 9,817; 1.3%), all metals, were rejected due to various quality control deficiencies or uncertainties. As a result, the presence or absence of these analytes in the affected samples could not be determined. As summarized in Table 2 included on the accompanying CD, the metal results were rejected for the following reasons.

- The sample analysis was performed beyond the required holding time by more than 28 days. Four cyanide results were rejected for this reason.
- The matrix spike recovery was more than 200%. Fifteen arsenic results were rejected for this reason.
- The matrix spike recovery was less than 10%. Fifteen copper results were rejected for this reason.
- The difference between serial dilution analyses was more than 100%. Nine barium results, 17 cadmium results, and 17 lead results were rejected for this reason.
- The recoveries of the analysis of contract required detection limit standards were less than 50%. Fifty-three silver results were rejected for this reason.

As a whole, the completeness of sediment data collected at Kirkwood Lake is about 98.7%, greater than the completeness goal of 80% specified in Section 4.2.3 of the EPA-approved QAPP. The completeness of each metal was also examined, which can be found in Table 3 included on the accompanying CD. As indicated in this table, 1.7 – 22% of the sediment for any particular analyte were rejected with completeness ranging from 78% to 98.3%. Although 53 out of 236 (22%) silver results were rejected, this only represents 0.94% (53 out of 5,664) metal results collected for the sediment samples at Kirkwood Lake. Since silver is not a key constituent of concern, Sherwin-Williams does not believe that the lower than desired completeness score jeopardizes the quality of the investigation nor does it require re-sampling.

3.4 Simultaneously Extracted Metals/Acid Volatile Sulfide (SEM/AVS) Analysis and Organic Carbon Binding Capacity

The SEM/AVS method yields an indication of sediment toxicity to benthic organisms by providing a measure of the bioavailable fraction of metals in sediment (EPA, 2005). Studies have shown that insoluble metal sulfides, typically iron and manganese sulfides, control metal availability in anoxic (oxygen poor) sediments. The SEM/AVS method is applicable to six metals that react with sulfide to form insoluble metal sulfides: cadmium, copper, lead, nickel, silver and zinc. A comparison of the levels of AVS to the amount of available metal (SEM) indicates whether there is sufficient AVS to effectively sequester the available metal species, and reduce availability to receptors.

Cationic or SEM metals (cadmium, copper, lead, nickel, silver and zinc) bind with acid volatile sulfides in the sediment, thereby reducing the bioavailability of those metals in anoxic sediments. If AVS are present in the sediment at concentrations greater than the concentrations of the SEM metals, a line of evidence that the metals are predominantly present as metal sulfides, with limited bioavailability, is established. If, however, the concentrations of these SEM metals are greater than the AVS, the metals exceed the binding capacity of the sulfides, and are bioavailable.

The organic carbon fraction (foc) is also an important consideration in evaluating the potential bioavailability of the metals found in sediment. Some metals may preferentially partition to the organic carbon fraction, which will limit their solubility in pore water and, therefore, the bioavailability of the metal. The combined effect of the formation of insoluble sulfides and the foc can be evaluated by using the relationship of $[(\Sigma \text{SEM}) - \text{AVS}] / \text{foc}$. If these SEM metals also exceed the capacity of the total organic carbon to preferentially partition the metals to the sediment, rather than the water, then the sediment conditions may be toxic to benthic invertebrates. EPA (2005) has found that acute and chronic toxicity are not likely where this ratio is less than 130 and 28, respectively.

Therefore, the SEM/AVS ratio and $(\Sigma \text{SEM}) - \text{AVS} / \text{foc}$ parameter provide a preliminary indication of the bioavailability of the SEM metals found in sediment to benthic organisms. These results are typically utilized in combination with other factors, including sediment toxicity testing and benthic surveys to fully evaluate the potential for constituents in sediment to represent an ecological impact.

Sherwin-Williams collected and analyzed six samples for simultaneously extracted metals/acid volatile sulfides (SEM/AVS) during the June 2008 event. Sediment samples were collected from the 0.0-0.5-foot intervals in the fine-grained organic layer, using an Ekman sampler at sediment locations KWDD0005, KWDD0018, KWDD0025, KWDD0036, KWDD0055, and KWDD0105 (see Figure 1). The samples were collected prior to any deeper sampling that may have been conducted at each location. Each sample location was located by the GPS that has been used to mark locations throughout the course of the sampling activities.

The samples were selected to provide an understanding of the SEM/AVS ratio over a range of metals and TOC levels. All locations except KWDD-0105 were also included in the deeper coring program. KWDD-0105 was selected because of the elevated lead levels (2,520 mg/Kg and 3,540 mg/Kg [duplicate]) found during the October/November 2007 sampling.

The table below includes data excerpted from Table 1B and summarizes the results of the SEM/AVS analysis and the $[(\Sigma \text{SEM}) - \text{AVS}]/\text{foc}$ analysis.

SEM/AVS Sample Results

Sample ID	SEM/AVS Ratio	TOC mg/kg	$[(\Sigma \text{SEM}) - \text{AVS}]/\text{foc}$
KWDD0005-SD-AA-AB-0_A	0.72J	131,000J	-0.63
KWDD0018-SD-AA-AB-0_A	1.4J	111,000J	0.48
KWDD0025-SD-AA-AB-0_A	2.0J	45,600	0.20
KWDD0036-SD-AA-AB-0_A	0.59J	183,000J	-1.1
KWDD0055-SD-AA-AB-0_A	0.74J	142,000J	-0.65
KWDD0105-SD-AA-AB-0_A	3.8J	135,000J	1.2

As shown, the SEM/AVS ratio in three of the six locations was less than one, and the $[(\Sigma \text{SEM}) - \text{AVS}]/\text{foc}$ ratio in all locations was less than 28, the value at which chronic toxicity is considered to be unlikely. These results provide preliminary lines of evidence that, despite the presence of several metals at concentrations exceeding the LELs, there is a basis to predict that impacts to benthic organisms may be limited.

It is stressed that these results are preliminary and are not being relied upon as stand-alone data to develop conclusions regarding ecological impacts in the lake sediment. As stated previously, SEM/AVS results are typically viewed within the context of the bulk chemistry, benthic surveys and toxicity testing. Additionally, SEM/AVS ratios are not applicable to arsenic, one of the constituents found most frequently in the lake sediment. However, research on the geochemistry of arsenic provides an indication that, under anoxic conditions and in the presence of sulfur, arsenic will also precipitate, or co-precipitate with iron, as an insoluble sulfide.

4.0 SOIL INVESTIGATION

During the soil investigation activities, soil samples were collected from the southern shoreline (bank) of the lake as a continuation of the sediment transects. Soil samples were not collected from the northern shoreline of Kirkwood Lake, since residential sampling had previously been conducted under the oversight of the EPA Removal Branch. Samples were, however, collected at the northern end of transects KWT-1 and KWT-2 since both ends of these transects fell on the Kirkwood Lake Dam. Soil samples were also collected from the banks of the Cooper River below the Kirkwood Lake dam outfall to a distance of 150 feet downstream from the White Horse Pike overpass. The sampling locations are shown on Figure 1.

In accordance with the approved work plans, the soil samples were collected at the top of the bank but no more than 5 feet from the water's edge. The XRF protocol was used to screen the soil samples. Consequently, if the XRF readings indicated additional horizontal delineation was required, one additional step-out location was located at a distance of 5 feet from the initial sample location.

Soil samples were collected via hand auger, or an ATV-mounted Geoprobe/MULE rig depending upon accessibility. All sampling equipment was decontaminated prior to use. All samples were placed in laboratory prepared bottles, preserved as specified in the EPA-approved RI/FS QAPP, and submitted for laboratory analysis. The laboratory analytical results may be found in Table 4B.

A total of 75 unique soil samples and two duplicates were collected during the November 5-14, 2007 and February 5, 2008 sampling events. On February 5, 2008 soil samples were collected at depth from the ends of transects KWT-1 and KWT-2 (located on the Kirkwood Lake Dam) using a Geoprobe rig. All samples were submitted to Test America Laboratories for TCL PAHs, TAL metals, and percent solids analyses. During these events, six samples collected on the bank of the lake required additional delineation by locating a step-out sample 5 feet away from the initial sample. The following table summarizes the six sample locations along the bank of the lake where step outs were conducted and the subsequent delineation locations:

Initial Sample	Delineation Sample(s)
KWSB0005	KWSB0011 (5' step out)
KWSB0009	KWSB0024 (5' step out)
KWSB0010	KWSB0036 (5' step out), KWSB0025 (25' step out)
KWSB0028	KWSB0038 (5' step out), KWSB0034 (25' step out)
KWSB0031	KWSB0035 (5' step out), KWSB0032 (25' step out)
KWSB0029	KWSB0037 (5' step out), KWSB0033 (25' step out)

As presented in the above table, four samples were initially collected as 25-foot step-outs, instead of the 5-foot step-outs specified in the work plan. Upon discovery, the field team returned and performed the 5-foot step-outs consistent with the approved Work Plan and the 5-foot step-out samples collected at other locations. As a result, the four

samples collected as 25-foot step outs were submitted for laboratory analysis and are included in the results presented in Table 4B.

Samples were collected from 38 locations, as compared to the initial 20 locations included in the scope of work in the work plan. Ten locations were added based on the results of the XRF field screening, as presented in the table above. Also, eight sample locations were added along the banks of the Cooper River, downstream of the Kirkwood Lake Dam, northwest of White Horse Pike.

4.1 Constituents Present in Soil

The sample analytical summary tables and laboratory analytical results for these samples are provided respectively in Tables 4A and 4B included on the accompanying CD. A soil statistical analysis summary is presented on Table 4C, also included on the accompanying CD. To assist in review of the results, the soil data are further presented in the following figures:

Figures 5 and 6: Analytical results for arsenic and lead in soil are presented in Figure 5; the data are compared with their respective soil remediation standard. Only the arsenic and lead analytical results greater than the NJDEP RDCSRS are shown on Figure 6.

Figure 6: All constituents detected in soil at concentrations above their respective RDCSRS are presented. As stated previously, the results presented for constituents other than TAL metals are from only the October/November 2007 sampling event.

As presented, 11 of the 77 samples contained one or more metals at a concentration greater than the NJDEP RDCSRS, and eight soil samples contained one or more PAHs at a concentration greater than the RDCSRS.

Arsenic was the metal most frequently detected at a concentration greater than its RDCSRS. Arsenic was found in seven samples and one duplicate at concentrations ranging from 21.1 mg/Kg to 55.8 mg/Kg.

Lead was found in three samples at levels greater than the RDCSRS. Lead concentrations ranged from 487mg/Kg to 1,680 mg/Kg.

Vanadium was found in one sample at a concentration greater than the RDCSRS.

Arsenic was the only metal found at concentrations greater than the RDCSRS at depth intervals below the surface. Arsenic was found at concentrations ranging from 21.1 mg/Kg to 55.8 mg/Kg in deeper intervals at locations KWSB-0006, KWSB-0010, KWSB-0018, and KWSB-0038. At location KWSB-0038, arsenic was found at a concentration of 22.5 mg/Kg at a depth of 6.0-6.5 feet. Arsenic was also the only metal found in a soil sample down stream of the Kirkwood Lake dam outfall to the Cooper River. Arsenic was found at a concentration of 21.1 mg/Kg in location KWSB-0018 at a depth of 2.0-2.5 feet.

Benzo(a)pyrene was the PAH most frequently found at a concentration greater than its RDCSRS, and was found in eight samples. Other PAHs found included benzo(a)anthracene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene. Concentrations of the individual PAHs were generally 1 mg/Kg or less, except at location KWSB0032, where higher concentrations of PAHs were found in the AE-AF interval.

The vertical and horizontal extent of the lead and arsenic was determined in the majority of locations. However, there remain some locations where complete vertical and/or horizontal delineation to the RDCSRS has not been completed. These are:

- KWSB-0006 – Arsenic is not vertically delineated;
- KWSB-0007 – Lead is not horizontally delineated;
- KWSB-0013 – Lead and arsenic are not horizontally delineated;
- KWSB-0018 – Arsenic is not vertically or horizontally delineated;
- KWSB-0035 – Lead is not vertically delineated; and
- KWSB-0038 – Arsenic is not vertically delineated.

As discussed in Section 7, Sherwin-Williams is proposing to return to these locations to complete the vertical and horizontal delineation of the lead and arsenic. The same sample screening collection and analysis protocol used for the initial soil samples will be used to complete the horizontal and vertical delineation of lead and arsenic at the above locations.

Sherwin-Williams is not proposing to perform additional delineation for the PAHs detected in soil at the western perimeter of the lake and in soil downstream of the Kirkwood Lake outfall to the Cooper River. The PAHs were found only at the locations at the western end of the lake and down stream of the Kirkwood Lake dam, and it is unclear that their presence is associated with transport from Kirkwood Lake. The locations at which the PAHs were found are in relatively close proximity to the PATCO rail lines and/or White Horse Pike, both of which are potential sources of the PAHs. The absence of PAHs at concentrations greater than the RDCSRS in other sampling locations along Kirkwood Lake would tend to support a conclusion that the PAHs, where found, originate from a source other than transport from an upstream source to Kirkwood Lake.

4.2 Data Completeness

A total of 77 soil samples, including two field duplicate samples, were collected and submitted to laboratory for analyses of TAL metals, PAHs, and percent solids. A query of the Kirkwood Lake database yielded no result rejections in soil samples, thus

deemed 100% complete. Although some results were estimated due to slight QC deficiencies, the data set is of sufficient quality to be used in the evaluation of the distribution of constituents in soil at Kirkwood Lake.

5.0 SURFACE WATER INVESTIGATION

Surface water samples were collected from 10 locations, along with one duplicate sample, at the approximate midpoint of each sediment sampling transect and from 1 location in the pool below the dam outfall. The sampling locations are shown on Figure 1.

Samples were collected from approximately the mid-point of the water column. Therefore, where the water was three feet deep, the samples was obtained from a depth of approximately 1.5 feet below the surface. The surface water samples were collected with dedicated Teflon tubing attached to a peristaltic pump. The tubing was inserted into the water column to the appropriate depth, and the pump was used to collect the samples. The samples were not filtered.

The aqueous samples were transferred into laboratory prepared bottles, preserved as specified in the EPA-approved RI/FS Quality Assurance Project Plan, and submitted to Test America for TCL PAHs, TCL PCBs, TAL metals (total), hardness, pH, and TOC analysis. The sample analytical summary tables and laboratory analytical results for these samples are provided respectively in Tables 5A and 5B included on the accompanying CD, and the exceedances are also presented on Figure 7.

Lead and arsenic concentrations detected in all surface water samples exceeded the NJDEP surface water quality criteria for freshwater – human health as published in 2008. Only lead was found at a concentration greater than the NJDEP 2008 FW2 chronic criteria for protection of aquatic resources. No other constituents were found at concentrations greater than the FW2 criteria in any sample.

It is likely that the absence of filtering has affected the surface water results. For example, while lead was consistently found at concentrations of approximately 15 ug/L in the majority of the surface water samples collected, the lead concentration at location KWDW0010 was 99.3 ug/L. It is highly unlikely that the dissolved-phase lead concentrations would vary so dramatically within the lake, and the reason for the elevated levels in KWDW0010, as compared to other locations, was the presence of sediment particles in the samples. The extent to which sample turbidity and the presence of sediment particles affected the results reported in other samples is unknown.

Regardless, however, of the possible effects of turbidity on the reported sample results, the characterization of surface water in Kirkwood Lake for purposes of the Remedial Investigation is considered complete. If required, Sherwin-Williams will return to Kirkwood Lake and collect additional filtered and unfiltered surface water samples to support the risk assessment and/or the feasibility study. If it is determined that additional samples are to be collected, a separate work plan specifying sample collection, filtering and analytical procedures will be submitted to EPA.

A query of the Kirkwood Lake database yielded no result rejections in surface water samples, thus they are deemed 100% complete. Although some results were estimated, the data set is of sufficient quality to be used in the selection of the COPCs at Kirkwood Lake.

6.0 PORE WATER INVESTIGATION

Pore water samples were collected on November 8, 2007 from the approximate midpoints of transects KWT-2 (KWPW0001), located at the western, downstream end of Kirkwood Lake, and KWT-35 (KWPW0002), located at the approximate center of Kirkwood Lake. These samples were co-located with surface water locations KWDW0003 and KWDW0007, respectively. An additional sample was proposed at transect KWT-70 to be co-located with surface water sample location KWDW0011, but the sediments did not yield enough water to complete the sampling event. The sampling locations are shown on Figure 1.

The intent of the pore water sampling was to collect preliminary information regarding the bioavailability of the constituents found in sediment. As discussed in Section 3.4, there are several mechanisms, including the formation of insoluble sulfides and the preferential partitioning of constituents to organic carbon that would reduce the exposure of benthic organisms to these constituents. Pore water samples provide a direct measurement of these exposure levels.

Pore water samples were collected from temporary wells constructed of one-inch diameter, size 20-slot, PVC screen and solid PVC sections that were manually installed through the fine-grained organic material and into the deeper coarse-grained sediment, however, the screened interval was located within the fine-grained organic material. Solid PVC riser sections were installed in the upper water interval and within the deeper coarse-grained material and the 20-slot screened interval was used to collect the sample from the fine-grained organic layer. The solid PVC riser sections were used to isolate the sampling interval (fine-grained organic material) from lake water and / or water contained in the deeper coarse-grained material. Sediment cross-section profile measurements were used to determine the depth of the water column and thickness of the fine-grained organic layer and location of the deeper coarse-grained sediment to determine placement of the temporary well. A schematic of the temporary well construction is shown as Figure 8.

An initial attempt to collect pore water samples was made on October 31, 2007. As per the sampling protocol in the work plan, the temporary wells were installed in three locations, KWPW0001 (KWDW0003), KWPW0002 (KWDW0007), and KWPW 0003 (KWDW0011) on October 30, 2007. The wells were originally constructed using a 10-slot screen. When attempts were made to purge the wells prior to sampling, however, a very low recharge rate was encountered. Approximately 250 – 350 milliliters (ml) of water was obtained from location KWPW0001, while KWPW0002 was dry after only three minutes of purging, and KWPW0003 produced water for only five seconds.

A second attempt to collect pore water samples was made on November 8, 2007. The temporary wells were installed the day before on November 7, 2007, using a 20-slot screened interval in an effort to increase the recharge rate into the temporary wells. Samples were collected from KWPW0001 and KWPW0002, but even with the larger slot size, no samples could be collected from KWPW0003. As noted below, however, the increased slot size resulted in the presence of elevated total suspended solids (TSS) levels in the two samples that were collected.

The samples collected at locations KWPW0001 and KWPW0002 were placed in laboratory prepared bottles, preserved as specified in the EPA-approved RI/FS QAPP, and submitted for TCL PAHs, TCL PCBs, TAL metals (total), hardness, total dissolved solids, total suspended solids, and TOC analyses. The sample analytical summary tables and laboratory analytical results for these samples are provided respectively in Tables 6A and 6B included on the accompanying CD, and the exceedances are also presented on Figure 7.

The results of the pore water analyses found cadmium, chromium, copper and lead at concentrations greater than the calculated chronic FW2 surface water criteria.

As presented in Table 6B, however, the two pore water samples contained TSS at concentrations of 34 mg/L and 159 mg/L. The small grain size of the fine-grained organic material from which the pore water samples were obtained, combined with the larger slot size required to allow collection of an adequate volume of pore water for laboratory analysis, resulted in the presence of the solids in the sample. It is likely that the solids in the samples contributed to the results reported by the laboratory, but the extent to which the reported results reflect dissolved-phase and/or solid-phase concentrations is unknown. Therefore, the results reported for the metals are considered inconclusive.

Neither PCBs nor PAHs were found in pore water at a concentration exceeding the method detection limit for either constituent. The absence of PCBs and PAHs in the pore water samples, even with the elevated TSS levels, reflects the relatively low concentrations of both constituents in the sediment, and the preferential partitioning of the PAHs and PCBs to the organic carbon fraction in the fine-grained organic material.

There is a potential that additional pore water data may be needed to refine the evaluation of bioavailability of the metals in support of the risk assessment and feasibility study for Kirkwood Lake. If it is concluded that additional pore water data are required, Sherwin-Williams will prepare and submit to the EPA a separate work plan documenting the sample collection and processing methodologies that will be used.

7.0 FINDINGS AND RECOMMENDATIONS

The results of the two phases of investigation have generally provided documentation of the physical characteristics of the fine-grained organic sediment and the deeper coarse-grained material, and the distribution of constituents in sediment, soil, and surface water. As stated previously, difficulties with regard to sample collection and the elevated suspended solids in the pore water samples prevents a meaningful evaluation

of pore water conditions for metals. Additionally, data have been collected that provide preliminary evidence that the presence of acid volatile sulfides and elevated foc in the fine-grained organic material may limit the bioavailability, and therefore the impact on benthic organisms, of the majority of the metals found in the sediment.

Additional characterization and analysis work is needed, however. Activities that have been identified for future efforts at Kirkwood Lake include:

- Further characterization of arsenic and lead in soil along the southern shore of Kirkwood Lake is needed to completely define the extent to which these constituents are present in soil at concentrations greater than the RDCSRS.
- Further evaluation of potential background conditions and other potential anthropogenic sources of the constituents found in Kirkwood Lake sediment and the soil is needed to refine the preliminary observations that: a) PAHs and PCBs found in soil and/or the fine-grained organic material may originate from anthropogenic sources unrelated to the Sherwin-Williams sites located in Gibbsboro, New Jersey; and b) a combination of naturally-occurring conditions, discharges from upstream Sherwin-Williams sites located in Gibbsboro, New Jersey, and other anthropogenic discharges are responsible for the metals found in Kirkwood Lake sediment.
- Additional filtered surface water samples may be needed to support the risk assessment and feasibility study.
- Further sampling of pore water using a different technique than was used during the October/November 2007 investigation may be needed for risk assessment support.
- Benthic surveys and/or toxicity testing may be needed prior to conducting the risk assessment to supplement the SEM/AVS analyses conducted. As stated in Section 3.4, the SEM/AVS analyses that were conducted are not considered to definitively establish the risk to benthic organisms as a result of the metals found in sediment.

Sherwin-Williams is not proposing at this time additional investigation of the PAHs found in soil along the western portion of the southern shore of Kirkwood Lake and in soil and sediment downstream of the Kirkwood Lake outfall to the Cooper River, the arsenic and lead found in sediment samples downstream of the Kirkwood Lake outfall to the Cooper River, or the arsenic found in soil at location KWSB0018. It is unclear that the PAHs, arsenic and lead are associated with discharges at any Sherwin-Williams site located in Gibbsboro, New Jersey, and additional evaluation of background conditions and other potential anthropogenic sources of these constituents is needed prior to performing additional characterization. The arsenic at location KWSB0018 was the only location at which arsenic was found at a concentration greater than the RDCSRS, and the concentration found (21.1 mg/Kg) approached the RDCSRS of 19 mg/Kg.

8.0 REFERENCES

USEPA. 2005. "Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: Metal Mixtures (Cadmium, Copper, Lead, Nickel, Silver, and Zinc)." Office of Research and Development, National Health and Environmental Effects Research Laboratory. January. EPA/600/R-02/011.

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